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UNDERSTANDING TO PREDICT SOIL BEHAVIOR

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ABSTRACT: Understanding is needed to relate variation of shear strength of soil in different environment. The shear strength is determined by the parent material of the soil (mineral skeleton), pore fluid (distilled water/ saline water) and environment which changes from land areas to deep Ocean. The shear strength interpretation is extended to the environments of turbidity currents, carbonate compensation depth and abyssal plains. The abyssal plains maintain moderate shear strength. The abyssal plain is a controlled environment which controls any events of the restless earth around it. The Carbonate compensation depth influences both turbidity currents and abyssal plains. Based on the analysis and interpretation of documented cases this paper makes a new conceptual model in interpretation of the influence of Carbonate Compensation depth on turbidity currents in Abyssal plain and the geotechnical behavior of the sediments in Abyssal plains. Documented Cases are: 1) Liquid Limit of a soil calculated by using distilled water is not representative sample in marine condition. The distilled water overestimates Geotechnical property. 2) The failure envelope of reconstituted clay mixed with distilled water is different from the one mixed with Nacl solution. 3) The Oedometer test on undisturbed specimens exposed to distilled water display higher strains than tested in solution.

Keywords: Abyssal plains Carbonate Compensation depth Lysocline layer Reliability Shear Strength.

1. INTRODUCTION

Turbidity currents are a subclass of the broader category of density currents. Density Currents also are termed gravity currents. A density Current “is the flow of one fluid within another caused by the density difference between the fluids. Turbidity currents exist when the density difference is due to suspended sediment and of course the fluids involved are both water. The weathering and stress history of the continental Rock transported as sediment as varying stages to abyssal plain meets varying or different environmental conditions on the way. Any Experimental data collected on Continental areas should be viewed with environmental information as an additional parameter to interpret Marine conditions. A few documented cases are discussed below.

2. DOCUMENTED CASES

2.1. Case (i) Effect of Distilled Water and NaCl Solution on Liquid Limit of Soil Samples

The liquid~~ity~~ limit obtained with distilled water is about two times the one obtained with Nacl solution, regardless its molarity.
A soil with a higher liquid limit will settle more. Distilled water is not a suitable pore liquid because it helps to obtain more settlement. In this context saline water is a better pore fluid compared to distilled water. The salinity of fresh water is in between distilled and Saline Sea water.

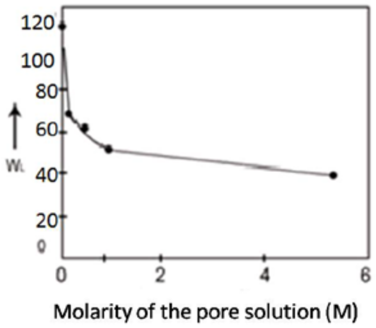

Fig. 1 Variations of liquid limit value with pore water types [1]

2.2. Case (ii) Odometer Test with Distilled Water and NaCl Solution of Soil Samples

An example of possible effects of infiltration of fresh water in a natural deposit subjected to swelling is shown in fig (2). The results of an Odometer tests carried out on two couples of undisturbed specimens of a type of clay shale taken respectively at a depth of 2.5 and 21m. A specimen of each couple was tested in a 1 m NaCl solution. The influence of the nature of the bath does not appear significant in the stage of compression, when the pore water is expelled from the specimen, but becomes prominent in the following stages of swelling, when some liquid is absorbed from the bath. The specimens tested in the distilled water (and specially the one taken at the greatest depth) display higher strains than those tested in the solution.

At the end of the tests performed in the NaCl solutions, when the axial stress was 10 kPa, the solution was substituted with distilled water giving immediately rise to further strong soil deformation.

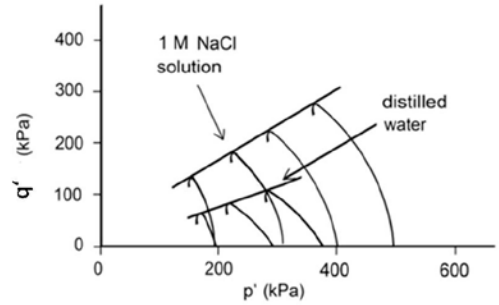

Fig.2 Odometer test with distilled water and NaCl [1] [2]

2.3. Case (iii) Triaxial Test with Distilled Water and NaCl Solution on Soil Samples

Fig (3) shows the results if a triaxial tests on reconstructed normally consolidated specimen obtained by mixing powdered clay with distilled water and a 1M NaCl solutions. It suggests that that a friction angle at constant volume (i.e. the critical friction angle) can strongly depend on the nature of the liquid. Similar data feature the residual friction
angle.

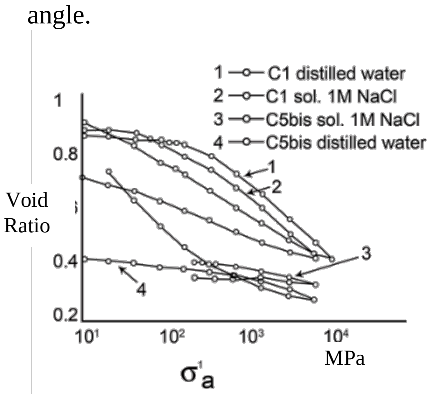

Fig.3a Triaxial test with distilled water and NaCl solution [1] [2]

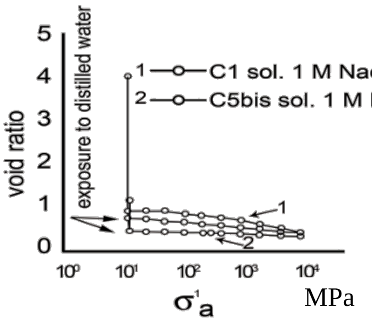

Fig. 3b Conventional test results with distilled water and NaCl solution on soil samples [1] [2]

2.4. Case (IV) Swelling Test on Soil Samples

Figure 4 shows the results of conventional tests conducted under a normal stress lower than swelling pressure (around 0.6 M Pa) while part of specimens were allowed to swell, as usual, for 48h,others were sheared only after 10-100 days during which they experienced a high volumetric strain. The difference in shear strength is very clear. All data show that swelling in distilled water as usual in laboratory, is responsible for a radical change in soil behavior. In addition fig 4 shows that the effect of swelling is higher if secondary swelling is allowed. The conceptual qualitative model of Turbidity currents: Repeated short term environmental changes influence in the long run the initiation of Turbidity currents.

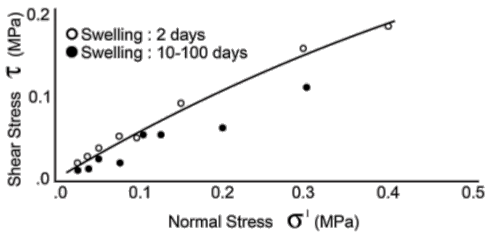

Fig.4 Swelling tests [1] [2]

3. UNDERSTANDING TO PREDICT SOIL BEHAVIOUR TO INCREASE RELIABILITY

3.1. Understanding to Predict shear strength of Land Fill (Soil) [3] [4]

Injection of Liquids in a Bio-Reactor Land Fill endangers the stability of waste mass slopes, for the following reasons.

1) Increased driving force due to the increase in unit weight of the waste mass due to liquid injection.

2) Decrease in strength due to decrease in the effective (inter-granular) stress corresponding to

the increase in pore pressure that result from liquid injection(leach-ate head build-up.

3) Decrease in strength due to transformation of Waste mass by the biological and chemical processes that enhance degradation, turning the waste into an inherently weaker material.

Lack of reliable data on shear strength of degraded waste is the main reason for all the problems/.

Isenberg et al (2001) conducted sensitivity modeling using a typical land fill.

Configuration to better understand how potential reduction in shear strength coupled with increases in unit weight will influence waste mass (soil) slope stability.

3.2. Understanding to Predict Shear Strength of Shallow Water Marine Sediment

Hyperpycnal flow: At a river mouth, a flow of river water that is denser than the water in the basin receiving it. This occurs during floods. The dense water flows beneath the basin water, as a density current, carrying sediment beyond the shore and inhibiting the pro-gradation of a delta

When Hyperpycnal flow erodes a shallow bed changes the soil behavior. Shallow layers of highly plastic marine OC clay subjected to swelling the shear strength decreases due to infiltration of fresh rain water which presents a very different composition than the natural pore liquid. The accumulated influence of the above changes in the environment will induce long term slope failure even in a gentle slope.

3.3. Understanding to Predict Shear Strength of Marine slope Sediments

Like Mineral Particles (Solids of the Soil Predominant) $CaCo_3$ Skeleton (particles) could be classified as Angular, Sub-angular, Sub-rounded, Rounded and well rounded. The angle of the internal resistance (phi) decreases due to weathering of particles from angular to well rounded stages. In the down slope depths the shear strength is less because angle of friction is less.

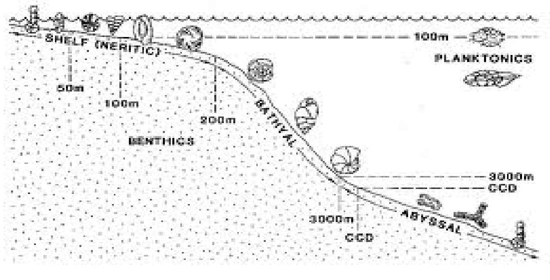

Fig.5a Representative foraminiferal types in the ocean today (Task 1988)

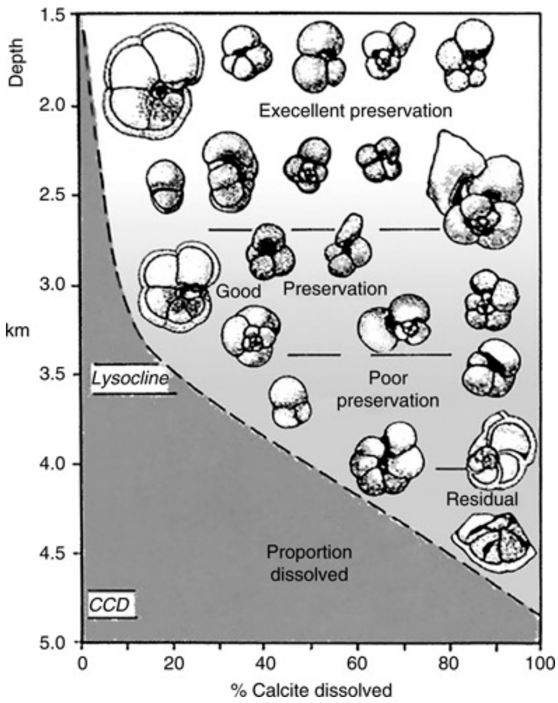

Fig. 5b % Dissolution of Carbonate with depth

3.4. Understanding to Predict Shear Strength of Marine Turbidity Sediments of Deep Water

3.4.1 Before passing through CCD

Carbonate Compensation Depth (CCD). $CaCo_3$ shells (tests) sink from surface water Tests may reach a depth where water is significantly under-saturated with respect to $CaCo_3$. At this depth, called Lysocline, shells begin to dissolve. In the modern Oceans, there is also a depth at which there is no longer any free $CaCo_3$. This depth, called the Cabonate Compensation depth CCD = - 4 Km. $CaCo_3$ tests accumulate only if they settle on Sea Floor above the CCD. Before passing CCD the shear strength is more because of the presence of $CaCo_3$ particles in the turbidity current as shown in figure 6a.

3.4.2 After passing through CCD

The final stage of Turbidity Current consists of hydraulic loading (saline water) Inorganic/Organic loading (includes mineral skeletons/Organic remains) and Velocity. The turbidity current Passing through CCD it begins to lose all the Calcium Carbonate particles. The Velocity of Turbidity Current slows down and the Shear Resistance decreases and spreads as Submarine fans as shown in figure 6b.

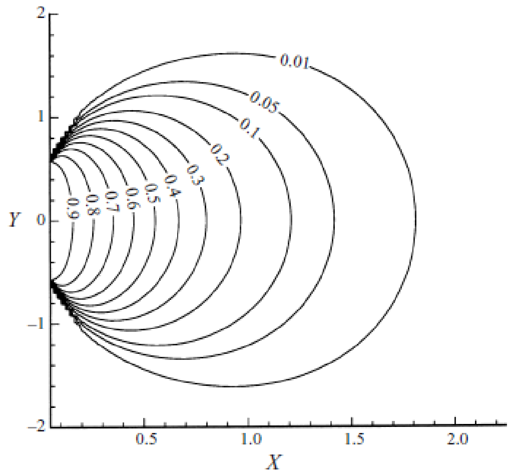

Figure 6a

Fig.6a Turbidity deposits on a horizontal slope with contours. Before passing ccd.

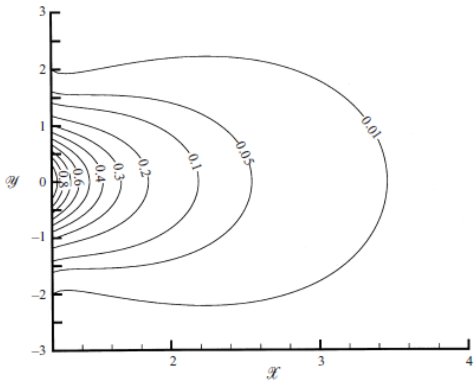

Fig.6b x- position of down slope y-position of cross slope. After passing ccd.

3.5. A Conceptual Hypo-Cycloidal Model and Explanation for the Behaviour of Turbidity Current

In Fig (7) the pore with Saline Water as Pore Fluid is shown as a circle with radius ‘a’ and the Solid Calcium Carbonate representing angle of internal friction, is shown as solid circle with radius ‘b’. In other words a solid circle with radius ‘b’ is rotating inside a fluid circle of radius ‘a’. At selected points on the circumference of this fluid circle the particle (CaCo3) makes contact to mobilize shear resistance. Taking a = R and b = r. The Selected number of contacts depends upon R/r ratio. The figure (7) is a self-explanatory for the particle behavior. Here the mathematics part is omitted.

Before reaching lysocline or CCD layer, the pore fluid and solid $CaCo_3$ fertile balance each other in strength to maintain dynamic equilibrium. The friction resistance is due to solid particle resistance balance each other the pattern of the fan is more or less circular in nature. When these solid particles are dissolved, the pore fluid circle alone exists with radius R. The small ‘r’ is already dissolved. The disappearance of solid particles and filling by fluid can be imagined, as reverse consolidations the fluid is expelled and solid particles come closer to each other. Where as in the marine environment (CCD) the solids is expelled and fluid is closer the space occupied by solid (CaCo3). Under these conditions the fluid dominates and the pattern of the fans are elongated elliptical one because the fluid after the collapse of the Turbidity Current will run further distance creating elliptical fans.

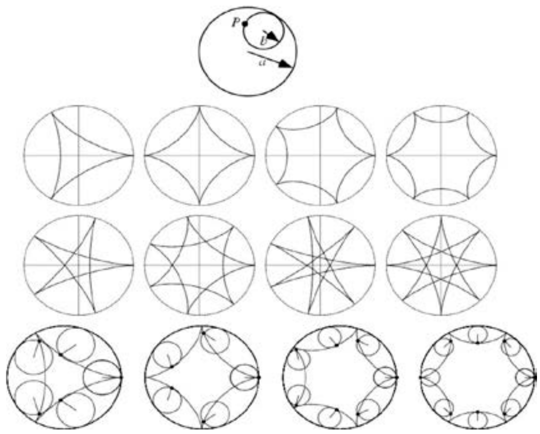

Fig. 7 Hypo –cycloidal model with different b values.

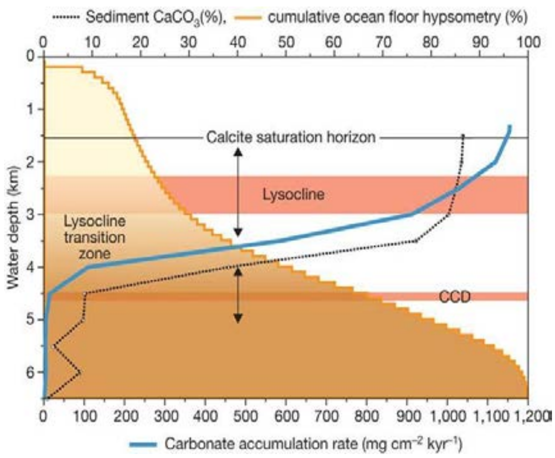

Fig.8 An illustration of the position of the ccd and lysocline and their relationship to ocean bathymetry, carbonate accumulation rate and caco3 content.

3.6. Understanding to Predict Shear Strength of Abyssal Sediments in Abyssal Depths with increase in Reliability.

The abyssal plain is a naturally Controlled environment which controls any event of the restless earth around it. In abyssal plain carbonates can not impart shear strength as particles but in dissolved state Calcium Carbonate with saline water can influence shear strength. In abyssal plain sediments derive shear strength from two sources (1) Cohesion of abyssal clay (pure shear or Coaxial component of shear strength). (2) Angle of internal friction (phi) from sand (Simple shear or Non-Coaxial component of the shear strength) along with mud and oozes. The third factor is saline water which modifies shear strength according to the environmental needs since CCD is not a fixed depth. It changes with environment and sensitive to Carbon stress from Continental areas.

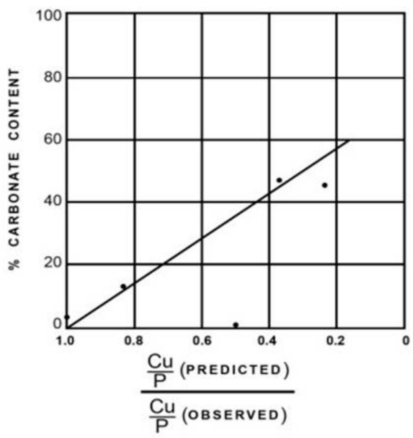

Fig.9 Influence of carbonate content on undrained strength of sediments from experimental Mohole. [5]

In Fig. 9 When the Carbonate percentage is very low the Cu/p predicted is equal to Cu/p observed, where Cu = un-drained shear strength and P = Vertical effective stress. This information increases the reliability and prediction becomes meaningful. Any additional information will always help in propagation of the predicted value of shear strength to the true value of shear strength of sediments.

4. CONCLUSIONS

1. Soils/ Sediments are Rocks on its way to Ocean.
2. The Moving Sediment is subjected to changing, environmental factors. The Shear Strength changes according to the existing conditions.
3. Starting from (urban) continental areas to deep ocean floor the reduced shear strength is a function of different environmental parameters.
4. The important environmental factors are:
   i) Saline Water ii) Hyperpycnal flow
   iii) Oversteepening of slope. iv) Calcium Carbonate shells. v) Lysocline layer.
   vi) Carbonate Compensation depth. vii) Flat or very slight slope of Abyssal plain. viii) Turbidity Currents. ix) Shape and size of Soil Particles. x) The resistance of sand and silt even in abyssal depth. Any combination of the environmental factors which will change the Shear strength of sediments will become the additional information and the reliability will increase the correct prediction of shear strength within that particular environment.

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